4-1998

The Effects of Directional Drying on Binder Migration

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by

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A Project Report submitted in partial fulfillment
of the requirements for the
Degree of Bachelors of Science
Department of Paper and Printing
Science and Engineering

Western Michigan University
Kalamazoo, Michigan
April 1998

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Binder migration or the nonuniform distribution of binder is a coating problem for many printing grades of coated paper. Binder migration causes mottle, dusting, non-porous coating and other problems in printing paper. Also, many coating dryers have extra capacity that cannot be utilized. The extra capacity goes wasted because at higher drying rates unacceptable binder migration would result.

If binder migration could be controlled, coated paper with better printing characteristics could be produced at higher speeds. This would result in a better product operating at higher speeds and a more satisfactory product to the printers.

The objective of this thesis was to study the effects of different drying ratios applied to the top and bottom sides of a coated paper. This objective was attempted by treating the two sides of the sheet independently with respect to drying. A special dryer was built to dry the coated sheets. The sheets were dried with 100%, 50% and 0% of the dryer air applied to the top. Then the samples were tested to evaluate binder migration.

This thesis showed that the sheets dried with air to the top and bottom were superior to those dried from one direction. This was not proven to be due to controlled binder migration. It did support the possibility that binder migration can be reduced.

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CHAPTER I

INTRODUCTION

Drying of paper coatings begins at the moment the coating formula is applied to the base stock. Drying conditions can strongly affect the binder distribution in paper coatings. Initially, paper coatings dry at the surface. Then, as the coating diminishes in volume to the point where the coating particles are packed together, drying occurs between the particles. The evaporation causes a meniscus to form between the particles. This meniscus causes a pressure difference between the side of the pore throat between the particles that is exposed to evaporation and the side that is wetted (1). The lower pressure at the evaporating surface pulls more liquid to that surface. Along with that liquid, binder travels to the evaporating surface. Binder concentration increases at the surface because it does not evaporate with the liquid. Evaporation usually happens in larger voids in the coating before the smaller voids. Also, the accessibility to vaporization further reduces the uniform distribution of binder. With a high drying rate, the meniscus travels down the pore throat faster than the liquid travels to fill that pore throat. Finally, the evaporation causes a void between the coating particles and the void jumps to coating particles away from the coating surface (figure 1) (2).

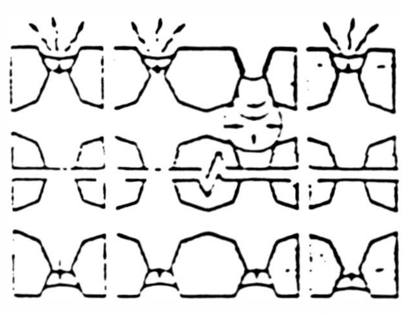

Figure 1: Coating surface drying model with a Haines Jump.

This travel from one pore throat to another is called a Haines Jump. This jump leaves the binder that has migrated nonuniformly in that position with no vehicle for it to travel back to a uniform distribution. If these jumps do not occur, all the binder would be deposited on the surface and the surface would be sealed. A sealed coating surface will not accept ink very well and will cause printing problems. If the jumps occur too fast, all the drying will occur within the coating and no binder will make it to the surface. This will cause dusting and the ink will pick off the paper during printing. This simplified model for drying is one of the most widely noted models in the literature (2).

CHAPTER II

BACKGROUND

In the past, binder migration wasn't the problem it is today. Drying rates were too low for serious binder migration problems. As the coater dryers developed higher drying capabilities, to keep up with faster run speeds, binder migration also grew as a problem. Finally, drying capabilities grew high enough in the coater dryers that binder migration became a limiting factor. The coater dryer could run far above what it is running at if binder migration were not a concern. Therefore, the extra dryer capability could be utilized for extra production if the binder migration could be reduced. The forces causing binder to migrate need to be in balance on the top and bottom sides of the sheet to immobilize the binder. It should be possible to do this by treating the two sides of the sheet separately. The literature cites many drying methods drying both sides of the web. Specific treatment of each side of the sheet is not found except for infra-red drying (3). IR drying can be applied to the two sides of the sheet at different power levels, but it is not treating the sides separately. IR drying from the coated side also treats the other side of the coating. IR can penetrate the coating, go into the base sheet, and be reflected back to the base sheet side of the coating. Therefore, a method of individually treating the two sides of a coated sheet is needed. With individual treatment, migration could be controlled by balancing the drying stresses.

CHAPTER III

EXPERIMENTAL DESIGN

For this thesis, a special dryer was built to dry the samples at different ratios on the top and bottom of the sheet. The coating was prepared using #2 clay and styrene butadiene latex. The coating was made to 55% solids. The amount of SB latex was 15 parts per hundred parts dry clay. The coating was applied to one side of an 8 by 11 inch piece of the base sheet using a drawdown bar. After coating, the sample was immediately placed in the special dryer (figure 2).

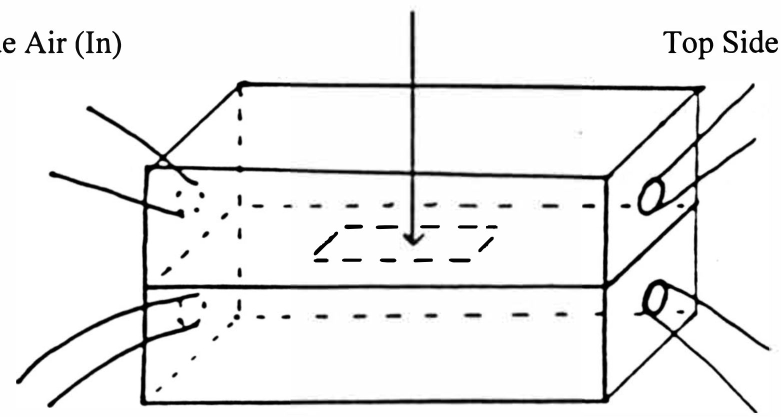

Figure 2: Dryer Design

The dryer consisted of two sealed boxes. Each box has an inlet and exit air port. Also, each box has a 6" by 7" opening to dry the sample. The sample was placed over the opening on the box with the sample opening up. Quickly, the second box was placed, sample opening down, matching the first opening. The boxes were hinged to speed up this process. The sample was sealed in the dryer by rubber seals around the perimeter of the sample openings. The sample dried in the area within the seals. The size of the openings was 6" by 7" to produce a 1" by 7" sample for IGT testing and a 5" by 7" sample for basis weight, Gloss and K&N.

The two sides of the samples were dried at different ratios. First, the 3 samples of 8 g/m2 coat weight were dried applying 100% of the dryer air to the top side of the sheet. *Then air was fed 50% to the top and 50% to the bottom of the coated samples. Then* 100% of the dryer air was supplied to the bottom of the sheet. This process was repeated for the 12 g/m2 samples. Many practice draw downs were performed until the desired coat weight was being produced. The dryer air was produced by a blower passing air through 3 electric heating elements. The air was ducted and gates installed to control the air to each side of the dryer. The samples were tested for basis weight, brightness, K&N brightness reduction, IGT pick, and gloss. The samples were supposed to be tested for surface binder by UV analysis, but this equipment was broken and not repaired before the time this paper was due. Presented in Appendix A is a flow chart of the experimental design.

CHAPTER IV

RESULTS

As can be seen in figure 3, the 50 / 50 samples had the highest gloss. This could be an indicator of good binder distribution. High gloss would mean the sheet reflects light well. The higher gloss could also mean the sheet is sealed due to all the binder migrating to the surface (4). Higher gloss in the 50 / 50 samples was a desired outcome. Unfortunately, under further analysis, the difference in the gloss results are not significant based on the standard deviation of the data.

Figure 4 shows that the 50 / 50 samples had the highest K&N ink brightness reduction. Under analysis, the results are significantly different. This supports the original objective. A high ink brightness reduction shows that the sheet has good ink receptivity. Poor ink receptivity could be caused by a sealed coating surface due to binder migration to the coating surface. The two tests work together. High gloss, low ink brightness reduction indicates a sealed coating surface. Low gloss, high ink brightness reduction indicates not enough binder at the surface.

IGT pick is a third test for binder migration. If coating can be picked off the surface, the coating is not bonded together and to the sheet. Very low picking could mean a sealed coating surface. Therefore, desired results would be low pick, high gloss and high ink brightness reduction. Unfortunately, in IGT testing for this thesis, all samples picked immediately at the start of the test. This results in a zero measurement. The 100 / 0 sample picked the most at zero. Then the 50 / 50 sample had the next most picking with the 0 / 100 sample with the least. An IGT ink with less tack was not available to obtain a number value. The difference in the amount of picking in the samples was easy to see and repeated for both the 8 and 12 g/m2 sample. With no value to the testing the results cannot be considered significantly different. The raw data for this thesis is presented in Appendix B. The original plan of this thesis was to use a UV analyzer for determining surface binder concentration (5,6). This test would confirm the binder, or lack of binder, at the surface of the sheet. The equipment was under repair during the testing phase and therefore the necessary tests could not be done.

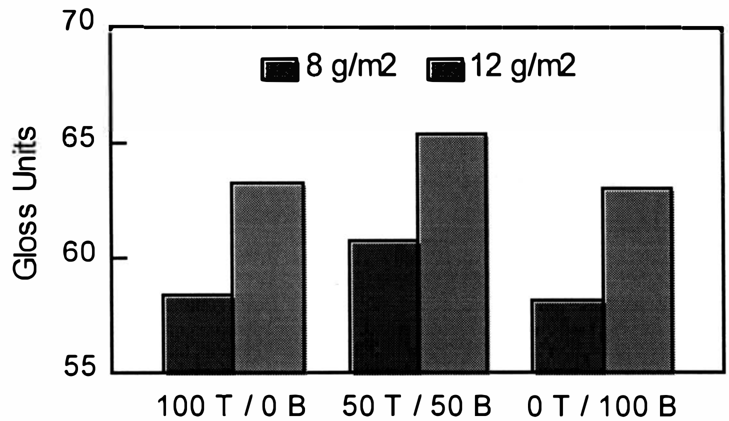

Figure 3: Gloss Results

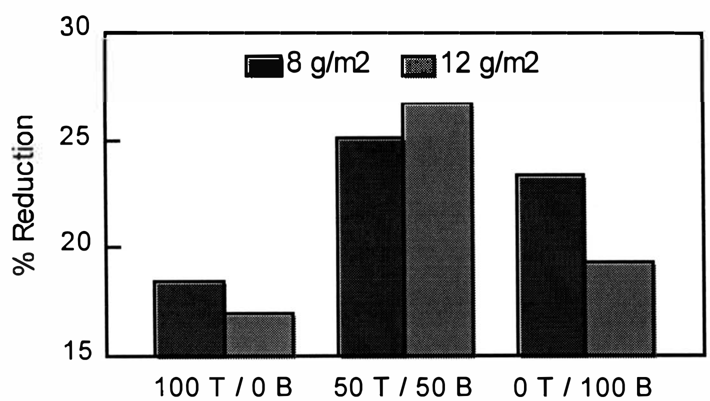

Figure 4: K&N Ink Brightness Reduction

CHAPTER V

CONCLUSIONS

The data obtained in this thesis had some favorable trends. Unfortunately, not all the results pointed toward the same conclusion. Some of the trends weren't statistically supported as significant. The testing did support the need for more experimentation. With the UV analyzer repaired, more significant results may have been obtained. The overall conclusion of this thesis is that controlling or reducing binder migration may still be possible by balancing the drying forces within the coating. This thesis did not, however, prove that conclusion.

CHAPTER VI

RECOMMENDATIONS

Further research would greatly be helped by a direct method of measuring the binder distribution in the coating. UV analysis of the surface binder would be a major step toward measuring binder. Also, testing at 75 / 25 and 25 / 75 ratios would be useful for establishing more meaningful trends. A more sophisticated dryer with measurement of the drying rates of the two sides of the sheet would be useful. In this thesis, it was assumed that under too much drying or too little drying, trends would still be produced.

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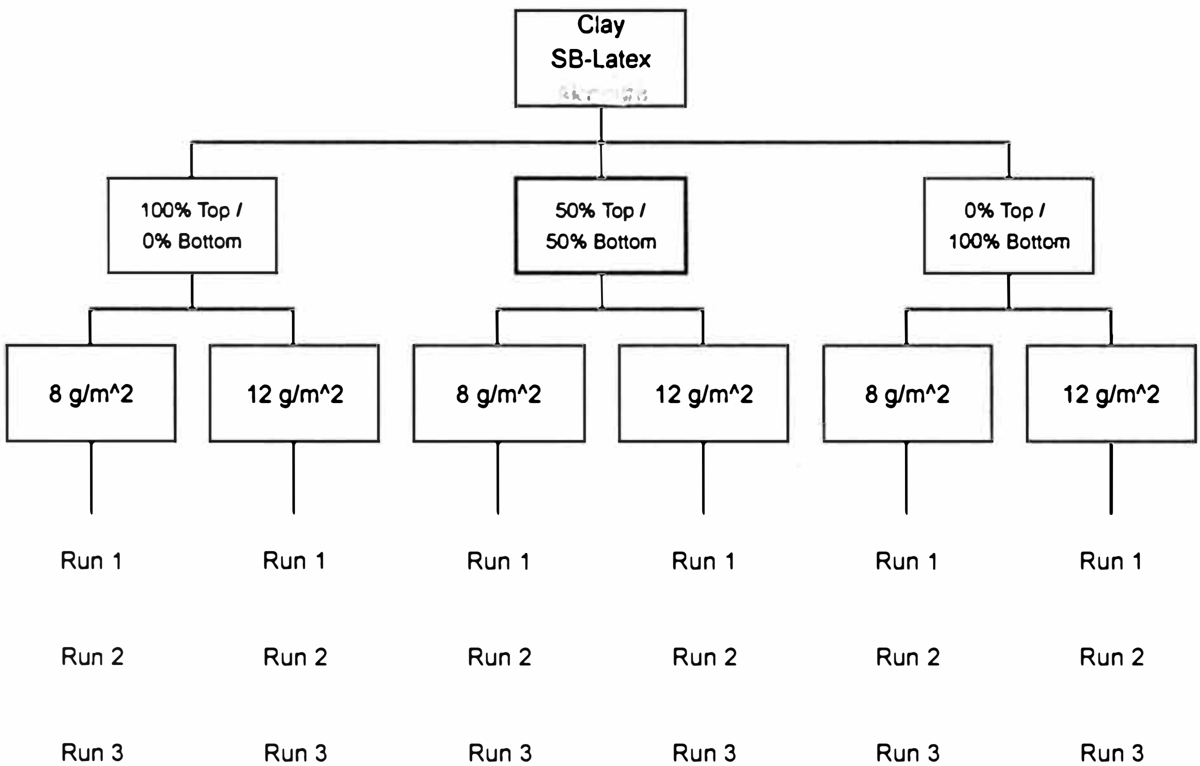
APPENDIX A

EXPERIMENTAL DESIGN CHART



APPENDIX B

RAW DATA

Coating Brookfield Viscosity	71 degrees F
	70.0 cp
	70.8 cp

COAT WEIGHT		Bas Wt	Ct Wt	
Base Sheet		96.2 g/m2		
100T / 0 B	L	102.7 g/m2	6.5 g/m2	avg of 3 sheets
100T / 0 B	H	109.8 g/m2	13.6 g/m2	
50T / 50 B	L	103.0 g/m2	6.8 g/m2	
50T / 50 B	H	109.4 g/m2	13.2 g/m2	
0T / 100 B	L	103.5 g/m2	7.3 g/m2	
0T / 100 B	H	109.3 g/m2	13.1 g/m2	

Gloss	100 / 0	50 / 50	0 / 100
8 g/m2	58.5	59.5	57.8
	58.6	62.8	57.5
	57.4	60.2	58.3
	58	60.2	58.7
	58.1	60.8	58.4
	59.9	61.3	58
12 g/m2	63.3	64.5	62.7
	63.4	68.1	62.3
	62.1	65.2	63.1
	62.7	65.2	63.7
	62.8	65.8	63.4
	64.8	65.4	62.9

Brightness	100 / 0	50 / 50	0 / 100
8 g/m2	81	80	81.2
	80.9	81	81.3
	81	80.8	80.9
	81	80.7	81.4
	80.5	80.8	81.3
	80.9	80.8	80.8
12 g/m2	78.1	78.2	78.7
	77	78.1	78.4
	77.9	77.2	78.8
	78.2	78.2	78.3
	78.4	77.7	78.9
	77.4	78.1	78.8

K&N Bright	100 / 0	50 / 50	0 / 100
8 g/m2	65.6	59.3	62
	65	57.6	62.6
	67.1	58.1	61.9
12 g/m2	64.8	57.4	63.1
	64.1	57.6	63.7
	64.9	56.1	63.5
IGT (8 & 12)	0-	0	0+